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AUTOMATION AND MANKIND

By V. A. Trapeznikov

- USSR -

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AUTOMATION AND MANKIND

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[Following is a translation of an article by V.A. Trapeznikov in Ekonomicheskaya Gazeta, 29 June 1960, page 1.]

On June 27, the first Congress of the International Federation on Automatic Control began its work in Moscow, in which about 1500 scientific and technical workers, from thirty countries of the world, took part.

The participants of the Congress listened with interest to the report of the Soviet scientist -- Academician V.A. Trapeznikov, on the subject "Automation and Mankind."

The report is published below:

Our congress is dedicated to questions of automatic control, questions of automation. What then is the general aim of automation? What can automation give mankind? To answer these questions, we will attempt to figure out the possible results of automation and ascertain what influence they will have on man in the future.

The first and main result of automation is the tremendous increase in labor efficiency. Of course, the increase in labor productivity and the growth of production of consumer goods will be the result of scientific and technical progress, and not conditioned solely on automation alone. A great role will be played here by the mastering of thermonuclear energy, the synthesis of artificial organic matter, right up to nutritive products, and the achievements of a great many other branches of science and technology. Today however, all branches of science are closer connected than ever before and their development is unthinkable without the use of automation is achievements. It is sufficient to bear in mind, that the accurate

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control of cosmic flights, the photographing of the moon and the relaying of its image to the earth, and the very existance of such powerful means of scientific research as the synchrophasotron, became possible only because of the achievements of automation.

Nevertheless, automation is still very young. The blossoming of automation is the business of the coming generations and only by general prognosis are we in a position to appraise what automation will give the people.

Upon automation will depend the tremendous growth of production; not only because it frees man from the immediate control of the machine but one individual will be able to control the work of many automated aggregates. Even more important is the fact that from now on, the development of production will not be limited by the capabilities of the human organism in the matter of control of its processes.

In our time, the speeds of technological processes are in many cases limited by conditions of control. The speed of human reaction is limited and therefore, at present, only processes of a relatively slow course can be utilized.

Automation is fated to reform in a revolutionary way, to change, the technology of the greater part of production, because it will become possible to control technological processes which flow at great speeds and on vast scales. If, up to the present, we have been compelled to limit ourselves with the use of stable technological processes, then, with automated control, it will be possible to also use unstable processes. It will become possible to control not only the results, but also the reactions of kinetics.

The mastering of atomic energy is one of the examples of an effective system of control making possible the use of extraordinarily dangerous objects for the welfare of mankind. The possibility of leading the technological process to the brink of a catastrophic situation, thanks to absolute faith in the instruments of automation, will also permit the use of such processes which now appear as inaccessible.

The goal of automation will be achieved when all the links of the regular production process are automated in all branches of industry, transport, and construction; including assembly, loading, and control, the packaging of products, and their transportation and movement along the trade channels to the consumer, i.e., when complex automatization is realized on a scale of branched

out systems with widely placed installations controlled by means of telemechanics, with a wide use of computers. It stands to reason that man will not be excluded from this process. Such functions as inspection, repair, study, and improvement will always require his more-or-less frequent presence. There can be no doubt that the opportunities of man in the field of control are great, and evidently will never be surpassed by machines in all ways. The rational use of man's capabilities in the systems of control and the creation of conditions in which the activity of man in the field of control of technical processes will flow most favroably, is the actual and noble problem of scientists working in the field of automation, physiology, psychology, technology of production, etc.

Automation not only multiplies the results of labor, but radically changes its character. Already a considerable number of heavy and dangerous jobs have been eliminated and this process will continue. In many cases the exhausting labor of the stoker has been abolished, the work of the steelcaster and blast-furnace operator has been considerably lightened. Looking forward, it can be foreseen that automation will completely free man from work under conditions of high temperatures, pressures, and polluted or harmful atmospheres. Automation will contribute to man's labor becoming more intellectual, to effacing the fine margin between physical and mental work, so that man's energy and strength in the field of production will all be to a greater degree used, not in the control of technological processes (and therefore not for physical work), but will be directed to thinking out and realizing new technical ideas.

The increase in labor productivity and the rise in production of consumer goods resulting from automation will raise sharply the living standard of the population and, in the not-too-distant future, permit a considerably shortened working day.

However, the full utilization of the benefits secured by automation is possible only in an intelligently organized human society, where people, freed as a result of automation, can be effectively used. According to our deep conviction which, it stands to reason, we do not force on anyone, such an organization of society is the socialist structure.

A sufficient amount of consumer goods will permit a considerable number of people to takeup scientific research work, protect the health of the population, embellish life (i.e., all forms of art), as well as the building of parks and gardens, public buildings, streets, etc.

The increase in leisure and in material means and possibilities will permit man, for the first time in history, to pay attention to himself, which he rightfully deserves. There will come a time of basic scientific care of the human organism and the systematization of nutrition and the daily routine, and sport and preventive treatment will take up a significant place. Considerably greater attention will be paid to the medical and biological sciences than is the case today. Let us hope that the success of these sciences will lead to the point where preventive treatment will become the basic occupation of doctors and each sickness will be viewed as an extraordinary occurrence. Automatons and semi-automatons for observation and registration of the conditions of the human organism, and for diagnosis and therapy, will constitute an important contribution to medicine.

Automation creations immense possibilities for the development of science. Let us remember, for instance the great problems of the breakthrough into the cosmos. The realization of interplanatory flights which, to a great extent, is due to the successes of automation, will evidently occur in our generation. The breakthrough into the cosmos will guarantee a speedy progress of our knowledge and the solution of many fundamental questions which run like a red line across the entire history of science. Problems of the origin of life, the existance of life outside the earth, the destiny of the earth as a planet -- these and many other questions which have always disturbed mankind, become close to being solved, thanks to the breakthrough into the cosmos, which also means thanks to automation.

Let us remember the problems of biology, and the adjustment and control in live organisms, which are directly linked to the problem of the origin of life. Undoubtedly, these questions will be speedily solved, also thanks to the use of methods of automation. In turn, the systems of automatic control of technical processes will be enriched through the study of live organisms.

With the development of automation, the forms and methods of scientific research in many fields of science and technology will change to a certain extent. Our time is charactrrized by the speedy development of the process of knowledge. There literally occurs a chain reaction in the growth of knowledge. The more we learn, the wider the horizons which open before us, and the greater the possibilities of acquiring new knowledge for the realization of new studies and discoveries. But in connection with this, new difficulties arise. On the one hand there are difficulties in storing great reserves of information

and their transmission in concise, condensed form. On the other hand, the very process of obtaining new information and the production of new research becomes, with the complication of the science, more and more laborious. Be it a question of thousands of experiments on variants of chemical reactions for the purpose of discovering new properties of chemical compounds, or be it the intention of studying live tissues, systems of conditioned reflexes, the laws of economics, or other complicated questions, a great deal of work of a highly qualified nature is required to learn the facts. In the future this work will be substantially supplemented and partially replaced by automation. Automatic systems, in which only a minimum of a priori information is supplied by the programmer, will produce information in new fields of knowledge. The researcher is already equipped with diversified measuring, registering, and calculating apparatus. A real research "industry" will develop even more on the basis of specialization, providing that cooperation, equipment, machines, and apparatus are available.

Automatons which help the researcher can be self-teaching. They can learn automations of a simple type, for the performance of simple tasks. However, in principle it is not impossible to work out to some degree "creative" practices, i.e., automatic improvement of research methods in complicated cases. At present, there is no limit to the development of such systems. It is not impossible to create an automaton which, on the basis of empirical data, by trying various hypothesis, could create complicated theories and explain experimental data in any field. Meanwhile, today, such work is called creative.

It stands to reason that, actually, the creative ability belongs not to the automaton but to the man who built this automaton. One cannot think of the automaton apart from the human collective which created it. Any machine, including an automatic one, is but the tool of the creative activity of man. But it can facilitate this work and enlarge and raise it to a level unimaginable at present.

The creation of electronic computers has shown how far one can go toward freeing man from operations requiring formal-logical thinking. However, it was a surprise even to the specialists as to how far the formal-logical thinking was cleared up and how complicated and deep the processes which, previously, only the human brain could accomplish and which now yield to automation, thanks to the use of computers.

The realization of mechanical translation from one language to another and the development of programs for solving problems would appear to be natural only for the brain -- for example, the solving of chess problems -- but, they have convinced many that formal-logical thought (i.e., that which lends itself to programming the spheres of the thought process), is much wider and more important that was previously believed. Where are the limits of these possibilities? How wide is the field of intellectual problems in which man can be replaced by the automaton? Are they limited by processes which are alogorithmized, or do they extend considerably farther? We look upon things of this kind with optimism, hoping that the possibility of lightening the mental activity of man is boundless, with the help of automation, and that the role of automation in this direction is most precious: freeing more and more the human brain from rough work, automation will permit the use of the inexhaustible resources of the human brain for feelings and creation.

The object of automation is a noble one; it is tangible and attainable. But to attain it, it is necessary to overcome a number of difficult problems. We will consider some of them.

In spite of remarkable successes in separate spheres of automatic-control theory, the general position on the theoretical front is not brilliant. First, this position is characterized as kaleidoscopic, with many separate theories, and lacking a single theory binding in structure. The general basic ideas, methods, concepts, and laws are in the process of creation, Second, a number of most important theoretical questions are not even worked out. The problems of theory are particularly apparent, when attempting to examine the complicated systems having an abundance of elements, and the connections between them. Here, not even a proper arrangement of problems has been worked out. Nevertheless, in the future, such systems will prove to be very real, since it is they who model some complicated functions of the activity of man.

At the same time, it should be emphasized that the theory of automatic control gradually changes its character, becomes in ever greater measure, the leading link in the solution of problems of automation. If before, the theory appeared basically helpful in the calculation of existing systems, now, and particularly in the future, the theoretical problems grow radically. Theory forms the scientific outlook of the engineer, guiding him in the search for essentially new types of systems. In an ever increasing degree, theory is beginning to serve as a "deep search,"

to clarify what the machines can and cannot do and how their possibilities can be increased.

Let us dwell on several most important scientific and technical problems characteristics of the modern stage in the development of automation:

1. Of great importance is the development of methods for the optimum control and synthesis of the structures controlling the devices which are close to the optimums.

The phase of these problems is extremely wide. Indeed, the objects which are being controlled may be linear or non-linear, with concentrated or distributed parameters, continuous or discrete. The criteria of the optimum may have entirely different characteristics on different occassions. The systems may be optimum by the speed of the transitional processes, accuracy in the programmed process, average production, etc.; and by the use of energy, raw materials, etc.

There exists at the present time general alternating principles, among which are the principle of the maximum and dynamic programming, which may form the basis for the solution of extraordinarily complicated problems. However, not all these principles have been generalized for a number of important cases. Moreover, their application to concrete problems generally require solutions of additional, complicated theoretical problems. The quite essential task of constructing simple systems which are close to optimums, is still insufficiently worked out. Therefore, in this field, there is still a great deal to be done.

2. An important problem is the working out of the principles of constructing self-adjusting and self-instructing systems.

The inclusion of highly developed arrangements of a logistic action and memory into the arsenal of automation means opened possibilities for the solution of a wide range of new problems of control. These are problems connected in a positive way with the establishment and support of the most advantageous system of work of the various objects of control, problems of the gradual development in the controlling devices of the desired reactions in complicated, changing situations, etc.

Along this course definite results have already been attained. Interference killing extreme regulators and multichannel optimizers have been created in the USSR for work under industrial and laboratory conditions. Substantial results have been obtained in the field of construction of self-instruction automatons. However, this

is only the beginning of an important direction.

The development of the principles of constructing automatic systems which solve such problems, their theory and calculation, are the actual problems of the theory of automatic control.

3. Of essential importance is the development of the principles of constructing automatons to design technical devices. Working out the structure of machines with a large number of elements often becomes too difficult for man or, in any case, does not guarantee attainment of the most rational solution. It is therefore also essential to use machines for designing.

In this field, theory is still very little developed and even the principles of constructing such automatons are in many ways not clear. It is possible that here, great help will be rendered by contact with physiologists and psychologists and by the calculation of the methods of solving such problems by man. These methods are characterized by low accuracy and speed, but on the other hand, in comparison with modern automatons, by astonishing flexibility and their adaptability to most diverse problems, and by "intuition," "phantasy," and their ability toward analogies and generalizations. Precisely in this field the theory of automatic control fits in more closely with cybernetics, the technical branch of which, so to speak, it is. Theory in the new and most interesting field of complicated automatons will evidently present itself as a unique fusion of the theoretical-logistic, statistical and, perhaps, variational methods. It is not excluded that here will emerge completely new ways of approach to the establishment and solution of problems. It is essential to push in every way the advancement in this direction.

Such research is being conducted in the USSR. A complex apparatus for automatic synthesis of optimum systems of control has been developed, a machine to analyse relay arrangements has been created, and a machine for the synthesis of structures of relay arrangements, which, under given conditions gives immediately the structure of a relay arrangement in a graphic image on a light background has been constructed for the first time. The construction of a machine to minimize Boolion functions is being finished.

However, these tasks must be taken as the first step towards the solution of the automation problem of the process of control-system synthesization.

Naturally, the above enumerated courses are not the only important ones. There is a number of other

actual problems: problems of stability, quality of control and search, theory of combined systems, etc. The latter, as well as the above enumerated problems, are linked together and will increase still more in the future. The connection of automatic-control theory with other sciences grows with the complication of the problems. We have already mentioned the connection with physiology and psychology. Connections with mathematics, especially with theoretical-logistic variants and statistical methods, should be noted.

Evidently, other new mathematical disciplines, such as functional analysis, could also find effective application in the theory of automatic control.

The development of technique and theory leads to the formulation of a single theoretical basis for the complex of technical disciplines relating to communication and control: automatics and telemechanics, radioelectronics, with all its branches, computation techniques, etc.

The theory which, it is true, is now only in its formative stage, is called the "theory of communication and control" or the "theory of control" or "technical cybernetics." But the point is not in the name, but in the crystallization of new ideas, principles and methods. The development of this single theory is extremely important for the matter of automation.

The development of the theory and technique of automatic control is impossible without progress in the apparatus of automatic control. The appearance of new types of apparatus and new physical principles of its construction, has always been a push towards qualitative changes, towards a new rise in automation, and it always stimulated the development of the theory of automatic control. It is sufficient to point out the deep influence produced on the development of automation by the appearance of electron computers of the continuous and discrete type.

In the field of construction of automatic-control apparatus, there are substantial achievements; however, here, too, there are still "gaps" -- problems awaiting their solution.

The most important problem in the development of control apparatus is increasing its dependability. In fact, the increase in the number of problems depending on control apparatus and the complication of these problems, leads inevitably to the increase in the number of elements of the apparatus and therefore to the possibility of increased disruption in the work of the system. If we figure on uninterrupted intensification of the processes and on increasing their scale, and, consequently, the results of possible breakdowns, it will become clear that

the problem of dependability is the key and, in essence, raises the question of "to be or not to be" of automation. The solution of this problem is proceeding along the line of development of more dependable elements and the means of connecting them, as well as in the search for methods of constructing dependable systems from unreliable elements.

The other important problem is the construction of control systems in the form of complexes, which unify standardized blocks permitting various combinations adaptable to requirements of one or another automated installation. This simplifies the planning and operation of the control system and lowers the general cost of automation.

Finally, the third important task is the development of miniaturized apparatus and the development of micro-elements, which is also connected with increasing the number of elements of control systems and with the demand for increased reliability.

These tendencies are illustrated by the development of electronic computing devices of discrete action. The stage of creating cumbersome mathematical machines with thousands of electonic tubes is being replaced before our eyes by a new stage -- the appearance of machines built of semi-conductor and magnetic elements. But even this stage is not the last one. Even now, signs of a new stage are emerging. It is possible that the new type machines will be based on new physical principles. The elements of such machines are magnetic tapes, cryogenic apparatus and others. Some of them can accomplish operations on the order of nano-seconds (10^{-9}) and are exceedingly small in size. Evidently the possibility of obtaining many thousands of memory elements in one cubic centimeter is sufficiently realistic. The new elements will possess high dependability, which, in a way, is connected with the new technology of their production and constructive application of uniting a multitude of elements into blocks, particularly by way of dusting tapes in vacuum, using the printed circuit technique for intra-blocking and interblocking contacts. In this direction, much has been accomplished by scientists of the Western countries.

Sometimes the well known elements of automation may appear in a completely new quality. For instance "old" pneumatic devices suddenly permit new solutions to be brought about in the control devices, which are based on reciprocity of air jets, as shown by work done in the USSR. With their help it is possible to create various control systems, including fairly quick-acting and highly

dependable digital computers for the control of processes. This trend will evidently revolutionize the construction of many systems of automation.

There is one more important problem which determines the success of automation, but far beyond the framework of questions of automatic control, which is what we are discussing at this congress. It is the problem of developing a technological process, the basic technological equipment, and the system of automatic control as a single, combined complex. Only such an approach affords the possibility of using all the advantages of automation. We in the Soviet Union, have chosen precisely this course.

In conclusion, I should like to touch briefly on the question of planning the development of science. The problem of determination of the optimum strategy of planning scientific research and the development of the technique does not have, and cannot have, a strict determination. Nevertheless, a certain amount of experience, accumulated in this field, makes it possible to correctly determine the basic question -- the question of correlation of current studies, subordinated to the interests of the present day, and the planned research which is aimed at the solution of the greatest problems of the future. It is quite clear that the role of planned studies must in the course of time increase, and their scale must be enlarged. This is the essential condition for genuine scientific and technical progress. But the larger the scale and role of planned studies, the harder it is to organize them. How do we limit the cases in which study in a new field, branching off at a tangent from the basic course, enters into an unplanned impass? In what way can we reduce the waste of energy and time connected with the tests and research in numerous, still uninvestigated directions? Not touching on other considerations in this respect, it can be ascertained that here, much depends on contacts and exchange of information among the scientists and specialists of different countries and professions. The greater the degree of cooperation, the quicker the unplanned directions are eliminated, the clearer will appear the main lines of development, and the more certain the advance along these lines. I am calling the scientists and specialists towards this cooperation on the important day of the opening of the First Congress IFAK for Automatic Control.

Great are the perspectives of human progress, part of which is the progress of automation. Only the monstrous and senseless catastrophe of war can hinder the avalanche-like and the all-accelerating progress of mankind. We are certain that this catastrophe will not come about, that

the nations will not permit it. Peace is the essential condition for the prosperity of mankind, for the development of the sciences, including automation.

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FOR REASONS OF SPEED AND ECONOMY

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